What are sunspots?

If the sun is viewed by projecting its image onto a screen, dark areas can be seen from time to time. These can last anything from a few hours right up to several weeks. These spots are cool areas (relatively speaking) on the surface of the sun. The temperature is around only 3000°C against a sizzling 6000°C for the rest of the surface. It is much hotter under the surface reaching temperatures in excess of a million degrees Celsius.

It is found that the number of sunspots on the Sun has a considerable effect on the levels of radiation emitted and hence impacting on the ionosphere. In turn this has a marked effect on radio communications of all forms. Sunspots are therefore of great interest to anyone involved in HF radio communications, as it affects the radio propagation conditions so significantly.

Sunspot activity has a major effect on long distance radio communications, particularly on the shortwave bands although medium wave and low VHF frequencies are also affected. High levels of sunspot activity lead to improved signal propagation on higher frequency bands, although they also increase the levels of solar noise and ionospheric disturbances. These effects are caused by impact of the increased level of solar radiation on the ionosphere.

Sunspots are indicators of disturbances in the Sun's magnetic field, which can generate energetic solar events like solar flares and coronal mass ejections. Since reasonably reliable records of sunspot counts extend back to the early 1700s, long before other measures of solar activity could be observed, sunspot counts serve as a valuable, relatively long-term indicator of solar activity. The Sun emits significantly more radiation than usual in the X-ray and ultraviolet portions of the electromagnetic spectrum during solar max, and this extra energy significantly alters the uppermost layers of Earth's atmosphere.

About Cycle :-

The 11-year sunspot cycle is actually half of a longer, 22-year cycle of solar activity. Each time the sunspot count rises and falls, the magnetic field of the Sun associated with sunspots reverses polarity; the orientation of magnetic fields in the Sun's northern and southern hemispheres switch. Thus, in terms of magnetic fields, the solar cycle is only complete (with the fields back the way they were at the start of the cycle) after two 11-year sunspot cycles. This solar cycle is, on average, about 22 years long - twice the duration of the sunspot cycle.

Diurnal, seasonal and geographic location effects on TEC variation:

The ionosphere is a layer in the Earth's atmosphere where free electrons exist in sufficient numbers to affect the propagation of electromagnetic waves especially the Global Positioning System (GPS) signals. The study of the Total Electron Content (TEC) variation in the ionosphere and structures is important to ensure the reliability of radio communication systems and accuracy of space weather forecasting. Since the GPS signals are broadcasted in two widely spread L-band frequency channels namely L1 and L2 consisting of code and phase, it is possible to determine the TEC by employing differencing techniques.

For example, In Malaysia This study is conducted using GPS data obtained from 50 stations all over Malaysia. The results of the diurnal analysis show that the mean TEC reaches its maximum during post local noon and its minimum during early morning. The results of the seasonal analysis show that the mean TEC during the equinox months is 35 TECU higher than during the solstice which is only 25 TECU. The seasonal effects on TEC variation is due to the location of the Sun, the movement of plasma around the magnetic equator, and the location of Malaysia. The latitudinal profile of TEC during equinox shows that the location of TEC maximum during the daytime is at southern Malaysia, but changes to the north during nighttime. During solstice, the location of TEC maximum during both day and nighttime is at northern Malaysia, while TEC maximum during early morning is located at southern Malaysia. These results can be used as a reference for ionospheric characterization over Malaysia.

Based on ionospheric total electron content (TEC) data for Zhongshan station (ZHS) and Scott Base station (SBA) in Antarctica, acquired during 2010–2020, high-latitude ionospheric TEC diurnal variations of two near cusp latitude stations were studied. The magnetic latitude and longitude differences between the two stations were approximately 5° and 135°, respectively. It was found that during the 11-year solar activity cycle, the maximum diurnal variation of the ionospheric TEC at ZHS occurred mainly between local noon and magnetic noon. Statistically, the TEC peaks occurred closer to local (magnetic) noon under low (high) solar activity conditions. The maximum diurnal variation of ionospheric TEC at SBA occurred mainly around local noon under low solar activity conditions but before magnetic midnight under high solar activity conditions. The effects of solar radiation, particle precipitation, and polar ionospheric convection pattern on the diurnal variation of TEC were investigated. At both stations, photoionization caused by solar radiation was the main reason for the maximum diurnal variation of ionospheric TEC around local noon. During high solar activity with high concentration plasma in the dayside polar ionosphere, the convection pattern was the dominant influence on the maximum diurnal variation of TEC before magnetic midnight (noon) at SBA (ZHS).

Seasonal :

Monitoring seasonal variations of ionospheric TEC using GPS measurements

The regional ionospheric model is adopted to determine satellite-plus-receiver differential delay. The satellite-plus-receiver differential delay is estimated as constant values for each day. Dual-frequency GPS pseudo-ranges observables are used to compute vertical TEC (VTEC). All the monthly mean VTEC profiles are represented by graphs using GPS data of the Beijing IGS site between 2000 and 2004. The monthly averaged values and amplitudes of VTEC are also represented by graphs. The results indicate that the VTEC has seasonal dependency. The monthly averaged values and amplitudes of VTEC in 2000 are about 2 times larger than that in 2004. The maximum VTEC values are observed in March and April, while the minimum VTEC values are observed in December

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geographical:

It is of great significance for the global navigation satellite system (GNSS) service to detect the polar ionospheric total electron content (TEC) and its variations, particularly under disturbed ionosphere conditions, including different phases of solar activity, the polar day and night alternation, the Weddell Sea anomaly (WSA) as well as geomagnetic storms. In this paper, four different models are utilized to map the ionospheric TEC over the Arctic and Antarctic for about one solar cycle: the polynomial (POLY) model, the generalized trigonometric series function (GTSF) model, the spherical harmonic (SH) model, and the spherical cap harmonic (SCH) model. Compared to other models, the SCH model has the best performance with ±0.8 TECU of residual mean value and 1.5–3.5 TECU of root mean square error. The spatiotemporal distributions and variations of the polar ionospheric TEC are investigated and compared under different ionosphere conditions in the Arctic and Antarctic. The results show that the solar activity significantly affects the TEC variations. During polar days, the ionospheric TEC is more active than it is during polar nights. In polar days over the Antarctic, the maximum value of TEC always appears at night in the Antarctic Peninsula and Weddell Sea area affected by the WSA. In the same year, the ionospheric TEC of the Antarctic has a larger amplitude of annual variation than that of the TEC in the Arctic. In addition, the evolution of the ionization patch during a geomagnetic storm over the Antarctic can be clearly tracked employing the SCH model, which appears to be adequate for mapping the polar TEC, and provides a sound basis for further automatic identification of ionization patches.

KP index :

The strength and impact of geomagnetic disturbances are estimated using geomagnetic indices like Kp, Dst, and AE, to name a few [12]. In this study, two indices AE and Dst are selected. Both the indices are available at 1-h interval while Kp index is a 3-hourly index. Furthermore, there is a good correlation between Dst and AE; hence, AE and Dst are selected for the study. The magnitude of these indices is determined using the horizontal H component of the geomagnetic field. These indices have a pattern characteristic pattern during quiet and disturbed conditions.

In the proposed work, an attempt is made to see if TEC can be used to study and understand the impact of space weather phenomena. This study of the dependency of TEC on AE and Dst indices can be helpful to understand the impact of space weather phenomena on the satellite-based system. The advantage of using TEC is its high temporal resolution as compared to other indices used for measuring geomagnetic storms like Dst and AE, which are available at 1-h intervals, or Kp, which is available at 3-h intervals. Furthermore, the equatorial ionosphere is characterized by large ionospheric gradients (even within 5°X 5° latitude and longitude). The deviations and perturbations in the TEC at different latitudes due to geomagnetic storms are also different. Thus, investigating the causality between the geomagnetic storm and TEC at the regional level can be useful in improving the existing methods used for correcting positional errors. This can be achieved with the high spatial resolution regional TEC data available from the GNSS receivers which have a wide global coverage. As causal inferences can result in the selection of physical quantities which are more informative, hence, the proposed study can be further combined with data-driven models for improved estimation of positional forecasting errors in the propagating signal.